Trapezoidal screw drives
Sizing and selection

Load rating of trapezoidal screw drives

As a general principle, the load rating of trapezoidal screw drives is dependent on their material, surface quality, state of wear, surface pressure, lubrication conditions, running speed and temperature, and thus on the duty cycle and the provision for the heat dissipation.

The permissible surface pressure is primarily dependent on the running speed of the screw drive.

With motion drives the surface pressure should not exceed 5 N per mm^2.

The permissible speed can be calculated from the supporting surface of the respective nut (see tables pp. 37 – 40) and the pv-factor of the respective nut materials (see p. 40).

pv-factors

Material	pv-factors [$N/mm^2 \cdot m/min$]
G-CuSn 7 ZnPb (Rg 7)	300
G-CuSn 12 (G Bz 12)	400
Plastic (PETP)	100
Cast iron GG 22 / GG25	200

Required bearing surface

$$A_{erf} = \frac{F_{ax}}{P_{zul}} \quad \text{(VIII)}$$

A_{erf}	Required bearing surface [mm^2]
F_{ax}	Total axial load [N]
P_{zul}	Maximum permissible surface pressure = 5 N/mm^2

Maximum linear running speed

$$v_{Gzul} = \frac{pv - factor}{P_{zul}} \quad \text{(IX)}$$

pv-factor	see table
V_{Gzul}	Maximum linear running speed [m/min]

Maximum permissible speed of rotation

$$n_{zul} = \frac{v_{Gzul} \cdot 1000}{D \cdot \pi} \quad \text{(X)}$$

D	Flank diameter [mm]
n_{zul}	Maximum permissible speed of rotation [rpm]

Permissible feed speed

$$s_{zul} = \frac{n_{zul} \cdot P}{1000} \quad \text{(XI)}$$

P	Thread lead [mm]
S_{zul}	Permissible feed speed [m/min]

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Example load rating calculation

Given: Screw drive,
Trapezoidal screw drive with bronze nut $P_{zul} = 5\ N/mm^2$,
Total axial load $F_{ax} = 10000\ N$

Required: What travel speed is still permissible at this load?

A_{erf} Required bearing surface [mm²]

from (VIII) $$A_{erf} = \frac{F_{ax}}{P_{zul}} = \frac{10000N}{5N/mm^2} = 2000mm^2$$

Selection of bronze nut EFM of technical data
➲ **page 39**

36x6 with bearing surface $A = 2140\ mm^2$

P Thread lead $= 6\ mm$

D Flank diameter $= d - \frac{P}{2}$
$= 36 - \frac{6}{2}\ [mm]$
$= 33\ mm$

V_{Gzul} Maximum linear running speed [m/min]

from (IX)
$$v_{Gzul} = \frac{pv - factor}{P_{zul}} = \frac{300N/mm^2 \cdot m/min}{5N/mm^2} = 60\ \ m/min$$

With pv-factor for RG 7 = 300 m/min
(see table)

n_{zul} Maximum permissible speed [rpm]

from (X)
$$n_{zul} = \frac{v_{Gzul} \cdot 1000}{D \cdot \pi} = \frac{60m/min \cdot 1000mm/m}{33mm \cdot \pi} = 579\ rpm$$

S_{zul} Permissible feed speed

from (XI)
$$s_{zul} = \frac{n_{zul} \cdot P}{1000} = \frac{579\ \ 1/min \cdot 6mm}{1000mm/m} = 3.474\ \ m/min$$

Result:

At a load of 10.000 N, the trapezoidal screw drive can be operated at a speed of 3.474 metres per min.

Trapezoidal screw drives
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Critical speed of trapezoidal screws

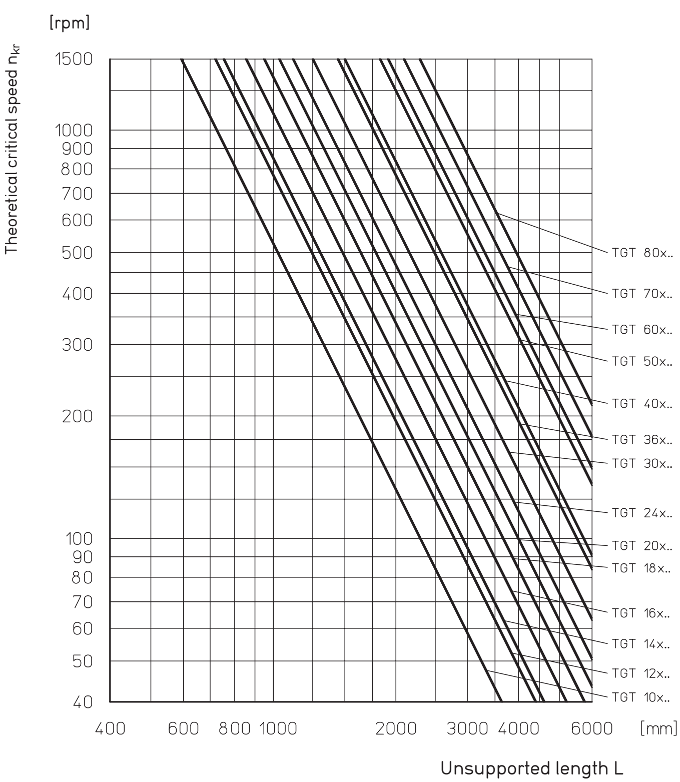
With thin, fast-rotating screws, there is the danger of "whipping". The method described below allows the resonant frequency to be estimated assuming a sufficiently rigid assembly. Furthermore, speeds in the vicinity of the critical speed considerably increase the risk of lateral buckling. The critical speed is therefore included in the calculation of the critical buckling force.

Maximum permissible speed

$$n_{zul} = 0.8 \cdot n_{kr} \cdot f_{kr} \qquad \text{(XII)}$$

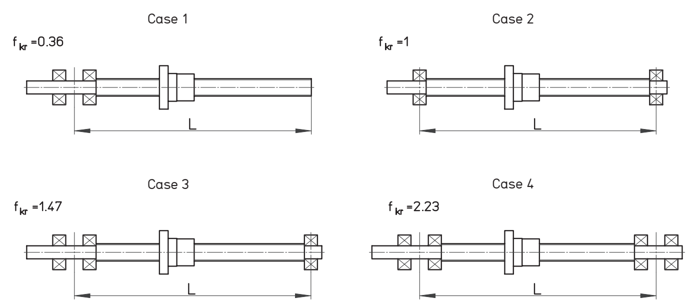
n_{zul}	Maximum permissible speed [rpm]
n_{kr}	Theoretical critical speed [rpm], that can lead to resonance effects ➲ see diagram
f_{kr}	Correction factor considering the bearing support of the screw. ➲ see table
!	The operating speed must not exceed 80% of the maximum speed

Theoretical critical speed n_{kr}



Bearing support

Typical values of correction factor f_{kr} corresponding to the usual cases of installation for standard screw bearings.



Trapezoidal screw drives
Sizing and selection

Critical buckling force of trapezoidal screws

With thin, fast-rotating screws under compressive load, there is the danger of lateral buckling. The procedure described below can be used to calculate the permissible axial force according to Euler.

Before the permissible compressive force is defined, allowance must be made for safety factors appropriate to the installation.

Maximum permissible axial force

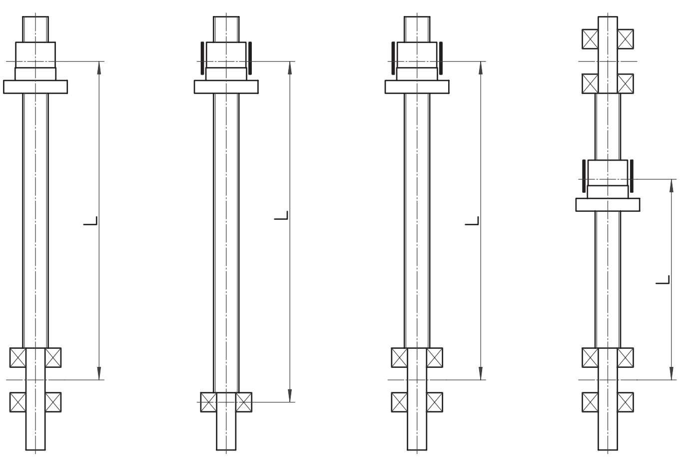
$$F_{zul} = 0.8 \cdot F_k \cdot f_k \qquad \text{(XIII)}$$

F_{zul}	Maximum permissible axial force [kN]
F_k	Theoretical critical buckling force [kN] ➲ see diagram
f_k	Correction factor considering the bearing support of the screw. ➲ see table
!	The operating force must not exceed 80% of the maximum permissible axial force

Bearing support

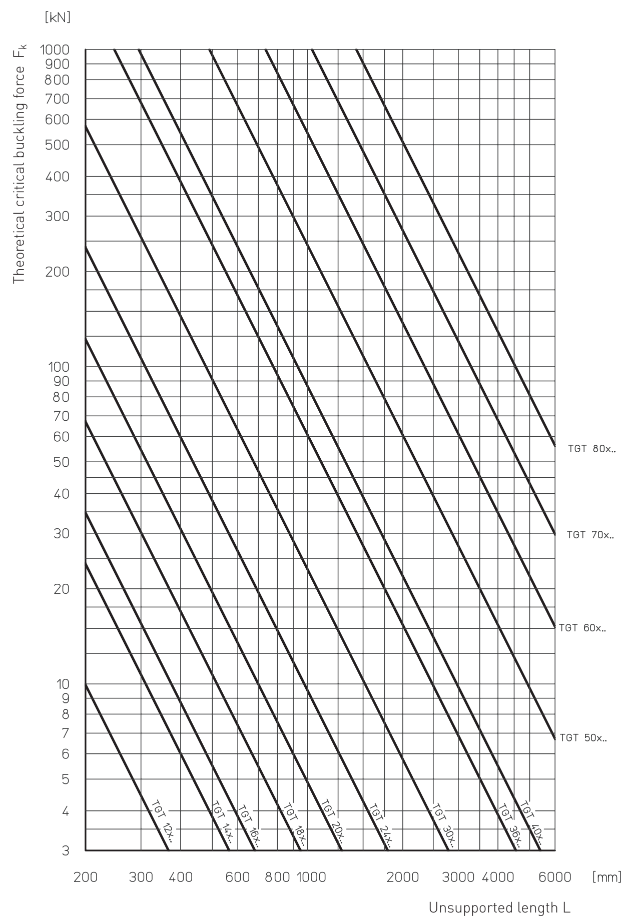
Typical values of correction factor f_k corresponding to the usual cases of installation for standard screw bearings.

Case 1 | Case 2 | Case 3 | Case 4



f_k=0.25 | f_k=1 | f_k=2.05 | f_k=4

Theoretical critical buckling force F_k



Trapezoidal screw drives
Sizing and selection

Deflection of the screw under its own weight

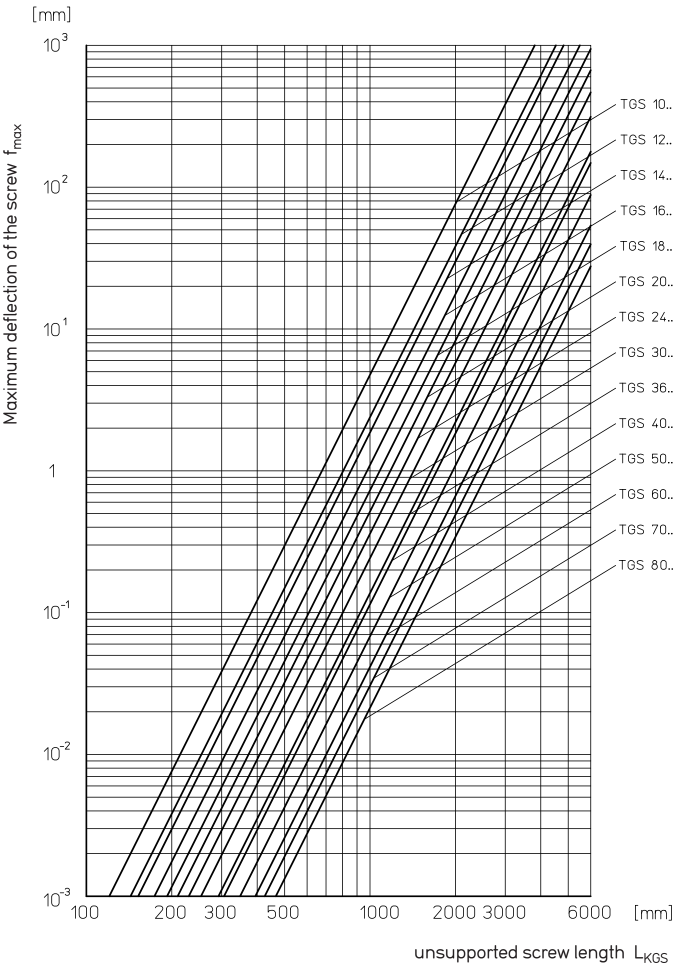
Even in the case of correctly installed screw drives where the resulting radial forces are absorbed by external guides, the weight of the unsupported screw itself may lead to deflection. The formula below allows you to calculate the maximum deflection of the screw.

Maximum deflection of screw

$$f_{max} = f_B \cdot 0.061 \cdot \frac{m'_{TGS} \cdot L_{TGS}{}^4}{I_Y} \qquad \text{(XIV)}$$

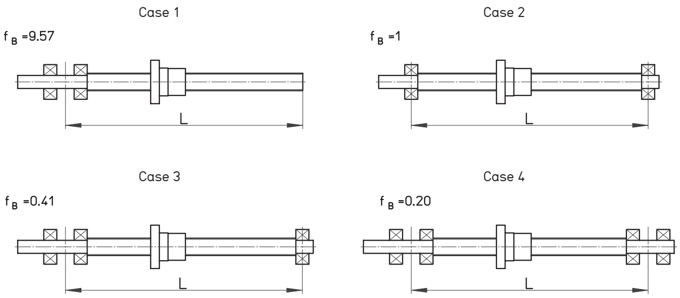
f_{max}	Maximum deflection of the screw [mm]
f_B	Correction factor considering the bearing support of the screw. ➲ see table
I_Y	Planar moment of inertia [10^4 mm^4] ➲ see table page 35
L_{TGS}	Unsupported screw length [mm]
m'_{TGS}	Weight [kg/m]

Theoretical maximum deflection of screw



Bearing support

Typical values of correction factor f_B corresponding to the usual cases of installation for standard screw bearings.



Trapezoidal screw drives
Sizing and selection

Example calculation for a trapezoidal screw drive

Given:
Trapezoidal screw drive,
Screw RPTS Tr 24x5
Length L = 1500 mm
Installation case 2
Maximum operating speed: n_{max} = 500 [rpm]

Required:
Is the operating speed uncritical?
What is the permissible axial force?
What is the maximum deflection?

Maximum permissible speed n_{zul}

from (XII)

$$n_{zul} = 0.8 \cdot n_{kr} \cdot f_{kr} = 0.8 \cdot 830\,\text{rpm} \cdot 1 = 664\,\text{rpm}$$

Theoretical critical speed n_{kr} = 830 rpm
➲ from diagram “Theoretical critical speed”

from (XIII)

$$F_{zul} = 0.8 \cdot F_k \cdot f_k = 0.8 \cdot 4.2\,\text{kN} \cdot 1 = 3.36\,\text{kN}$$

Theoretical critical buckling force F_k = 4.2 kN
➲ from diagram “Theoretical critical buckling force”

from (XIV)

$$f_{max} = f_B \cdot 0.061 \cdot \frac{m'_{TGS} \cdot L_{TGS}}{I_Y} = 1 \cdot 0.061 \cdot \frac{2.85\,\text{kg/m} \cdot 1.5\,\text{m}}{0.460\,\text{cm}^4}$$

$$f_{max} = 0.57\,\text{mm}$$

Weight m'_{TGS} = 2.85 kg/m
Planar moment of inertia I_y = 0.460 cm^4
➲ from table page 35

Result:

The selected screw drive is uncritical at n_{max} = 500 rpm.
It can be loaded with a maximum axial force of 3.36 kN,
and when installed horizontally has a maximum deflection of 0.57 mm

(Note surface pressure and pv-factor)

Trapezoidal screw drives
Sizing and selection

Required drive torque and drive power

The required drive torque of a screw drive results from the axial load, the screw lead and the efficiency of the screw drive and bearings. With short run-up times and high speeds, the acceleration moment should be checked.

Note: In case of trapezoidal screw drives, in principle, there is always a breakaway moment to be overcome.

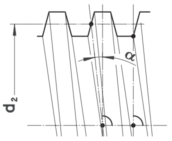
Required drive torque

$$M_d = \frac{F_{ax} \cdot P}{2000 \cdot \pi \cdot \eta_A} + M_{rot} \qquad \text{(XV)}$$

F_{ax}	Total axial load [N]
P	Thread lead [mm]
η_A	Efficiency of the overall drive $= \eta_{TGT} \cdot \eta_{fixed\ bearing} \cdot \eta_{movable\ bearing}$ $\eta_{TGT\ (\mu = 0.1)}$ ➲ see table page 35 $\eta_{fixed\ bearing} = 0.9 \ldots 0.95$ $\eta_{movable\ bearing} = 0.95$
M_d	Required drive torque [Nm]
M_{rot}	Rotational acceleration torque [Nm] $= J_{rot} \cdot \alpha_0$ $= 7.7 \cdot d^4 \cdot L \cdot 10^{-13}$ J_{rot} Rotational mass moment of inertia [kgm^2] d Nominal screw diameter [mm] L Screw length [mm] α_0 Angular acceleration [$1/s^2$]

Efficiency η for coefficients of friction other than $\mu = 0.1$

$$\eta = \frac{\tan\alpha}{\tan(\alpha + \rho')} \qquad \text{(XVI)}$$



η	Efficiency for converting a rotary motion into a linear motion
α	Helical angle of the thread [°] ➲ see table page 35 or in general $\tan\alpha = \frac{P}{d_2 \cdot \pi}$ with P screw lead [mm] d_2 flank diameter [mm]
ρ'	Thread friction angle [°] $\tan\rho' = \mu \cdot 1.07$ for ISO-trapezoidal thread μ is the coefficient of friction

	μ during start-up (= μ_0)		μ in motion	
	dry	lubricated	dry	lubricated
Metal nuts	≈ 0.3	≈ 0.1	≈ 0.1	≈ 0.04
Plastic nuts	≈ 0.1	≈ 0.04	≈ 0.1	≈ 0.03

Required drive power

$$P_a = \frac{M_d \cdot n}{9550} \qquad \text{(XVII)}$$

M_d	Required drive torque [Nm] ➲ from (XV)
n	Screw speed [rpm]
P_a	Required drive power [kW]

Trapezoidal screw drives
Sizing and selection

Torque resulting from an axial load

Trapezoidal screw drives with a helical angle α greater than the friction angle ρ', are not self-locking, i.e. the application of an axial load produces a screw torque.

Efficiency η' for converting a linear motion into a rotary motion is lower than the conversion of a rotary motion into a linear motion.

Required holding moment

$$M_d' = \frac{F_{ax} \cdot P \cdot \eta'}{2000 \cdot \pi} + M_{rot} \qquad \text{(XVIII)}$$

F_{ax} Total axial load [N]

P Thread lead [mm]

η' Efficiency for converting a linear motion into a rotary motion.

$$= \frac{\tan(\alpha - \rho')}{\tan\alpha}$$

$$= 0.7 \cdot \eta$$

The effect of the efficiency of the bearing is negligible.

M_d' Required holding moment [Nm]

M_{rot} Rotational acceleration torque [Nm]

$= J_{rot} \cdot \alpha_0$

$= 7.7 \cdot d^4 \cdot L \cdot 10^{-13}$

- J_{rot} Rotational mass moment of inertia [kgm^2]
- d Nominal screw diameter [mm]
- L Screw length [mm]
- α_0 Angular acceleration [1/s^2]